

The Management of Gases and Thermal Quantity in the Upper Zone of Electric Furnaces in Drenas

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Abstract-The paper's study objectives are problems encountered in the release and possibility of using the thermal gas quantity and application of methods and mathematical models to calculate the positive thermal effects of the gases and losses of thermal quantity with gases in the melting process of electric furnaces. The paper discusses in details the percentages of CO, CO₂, H₂S, O₂ and the humidity in gases and their impact on the technological process in electrical furnaces in Drenas. The paper also confers the quantity and temperature of gases, the transfer of thermal quantity and dust with gases in the environment. The paper presents the percentage of humidity in the load which is added in electric furnace for melting and its impact on thermal and environmental balance in the technological process of melting in electric furnaces.

Keywords-Furnace; Load; Temperature; Humidity; Gases

I. INTRODUCTION

Nickel easily reacts with gases in the atmosphere of the furnace in which the processes of producing the raw materials of nickel are developed. Such feature of nickel can explain the difficult processes of acquiring high quality nickel. Reductive atmosphere and the surrounding of gases composed of sulphureous anhydrite have harmful effects on production of nickel. Such occurrence is explained by the dissolubility of hydrogen and nickel oxide in the melted metal. Nickel reacts with carbon monoxide and forms carburetor of nickel and nickel oxide which dissolve in the melted metal. Carbon monoxide also dissolves in melted metal. The presence of carbon dioxide and water vapor in the atmosphere of the furnace impact the decrease of acidity in reductive atmosphere of the furnace. The carbon dioxide reacts with nickel and forms nickel oxide and carbon monoxide. Water vapor reacts with nickel and forms hydrogen and nickel oxide that have negative impact on the structure of nickel and its alloys. Based on these negative effects of gasses in the reductive atmosphere of electric furnace the paper has the analytical and experimental analyses of how to minimize the negative effects of gasses and humidity in the melting process of load in the electrical furnace in Drenas.

II. THE LOAD AND ITS COMPOSITION

The basic function of the rotational furnace department consists on drying and pre-partly reductive roasting of the ore which directly is loaded in the electrical furnace for melting. It is important to mention that the degree of roasting and pre-reduction of iron-nickel oxides is reached if the roasting process of the load in the rotational furnace is done in the temperature from 900°C–1000°C. With the reductive atmosphere in the furnace with minimal composition of oxygen in the gasses of the process, the optimal process of roasting and

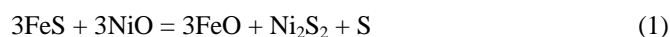
pre-reduction of the load in its mass is around 13%. With the removal of the humidity and the sterile pare of the ore, with the positive impacts in utilization of the thermal and electrical energy in the melting process in electrical furnaces.

III. THE LOAD OF THE ELECTRICAL FURNACE IN DRENAS

The supply of the electrical furnace is done with the hot load from 700°C-950°C is done through the system of bunkers and pipes set in the ceiling of the floor. The hot load with such temperature is the source of the thermal quantity which is used for part reduction of the load and the removal of the humidity from it. In this zone of the furnace we have the drying process with the reductive oxide dominated in the reductive atmosphere by the gasses composed of CO, CO₂, H₂O, SO₂, H₂S, etc. The quantity of the dusts in the gasses of the electrical furnace is about 1% of the mass of the load, and has the same chemical composition with the base load and is study object in this paper.

IV. THE THERMAL BALANCE OF GASSES AND THE HUMIDITY OF ELECTRICAL FURNACE IN DRENAS

The reaction in the process during the production of the oxide and oxidized ores of nickel rely on the diverse affinity of the iron and nickel on oxygen and sulphur. The essence of the process is included with the reactions.



Nickel with the sulphur is transformed in sulphur which together with iron sulphur forms the metaline-alloy Ni₃S₂-FeS, on the other hand the largest quantity of the iron in raw material percolate in grime.

The crucial characteristic of the melting in the electrical furnace is the phenomenon of foaming of the grime, this characteristic may have very negative consequences in the melting process. Foaming of the grime is a result of the fast formation of large quantities of the gasses which pass the 3 cm³ CO/m² min.

A. The Acquired Heat

The acquired heat for this zone of electrical furnace is mainly from the quantity of the load which is loaded in the furnace with the temperature of 700°C–950°C which is a value used in practice in the production of the iron-nickel metaline and the quantity of slit loaded in the electrical furnace in Drenas.

1) The Thermal Quantity Acquired From the Load:

The thermal quantity acquired from the load is calculated

with the expression:

$$Q_{\text{load}} = G_{\text{load}} \times C_{\text{load}} \times t_{\text{load}} \text{ kJ(h)}^{-1} \quad (3)$$

G_{load} – the quantity of the load loaded in the furnace is 1350 t(24h)⁻¹ used in the plant.

C_{load} – the specific heat in the load is 0.503 kJ (kg°C)⁻¹.

t_{load} – the temperature of the load 700°C.

$$Q_{\text{load}} = 56.25 \times 10^3 \times 0.503 \times 700 = 19805625 \text{ kJ(h)}^{-1}$$

Table I and Fig.1 presents the thermal quantity acquired with load depending from the temperature of the load which directly is loaded in the furnace.

TABLE I THE QUANTITY OF THE THERMAL HEAT ACQUIRED WITH THE LOAD CALCULATED WITH EXPRESSION (1)

Temperature °C	Load kg(h) ⁻¹	Thermal Quantity kJ(h) ⁻¹
700	56250	19805625
800	56250	45000000
900	56250	50625000

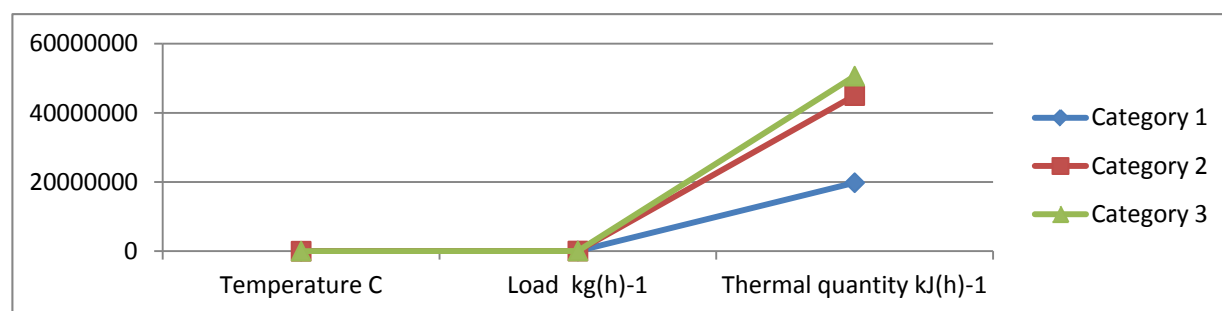


Fig. 1 The thermal quantity of the load

2) Thermal Quantity Acquired with Silt:

By loading of silt in electrical furnace, we help the technological process in this zone of the furnace and at the same time we increase the thermal quantity acquired in the process which is calculated with expression.

$$Q_{\text{Silt}} = G_{\text{Silt}} \times C_{\text{Silt}} \times t_{\text{Silt}} \text{ kJ(h)}^{-1} \quad (4)$$

G_{Silt} – the limit quantity is 48 t(8h)⁻¹ taken (used) in the plant.

C_{Silt} – the specific heat limit is 0.128 kJ(kg °C).

T_{Silt} – the limit temperature is 25 °C taken in the plant.

$$Q_{\text{Silt}} = 19200 \text{ kJ(h)}^{-1}$$

B. Used Heat

The used heat is the thermal quantity which is used for vaporizing of humidity from the load and thermal quantity used in the endothermic reaction. The thermal quantity lost is the thermal quantity of the gasses together with the dusts that exit in the environment.

1) The Thermal Quantity for Vaporizing Humidity:

The thermal quantity used for removal of the humidity from the load is calculated with the expression:

$$Q_{\text{vapor}} = G_{\text{load}} \times W_{\text{load}} \times 2448.8 \text{ kJ(h)}^{-1} \quad (4)$$

G_{load} – the load in the electrical furnace 1350 t (24h)⁻¹ or 56.25 t (h)⁻¹.

W_{load} – the humidity of the load which is around 10% up to 13% of the mass of the load

2448.8 kg (kg H₂O)⁻¹ is the quantity of the load which is used to vaporize 1 kg moist [2]. It is shown in Table II and Fig. 2.

$$Q_{\text{vapor}} = 56.25 \times 10^3 \times 10\% \times 2448.8 = 1377450 \text{ kJ (h)}^{-1} \quad (4)$$

TABLE II THE THERMAL QUANTITY USED FOR VAPORISING MOIST FROM THE LOAD BASED ON EXPRESSION (4)

The Percentage of the Moist in the Load	The quantity of the Moist in the Load kg	Thermal Quantity kJ(h) ⁻¹
10	5625	1377450
12	6750	16529400
13	7572.5	18543538

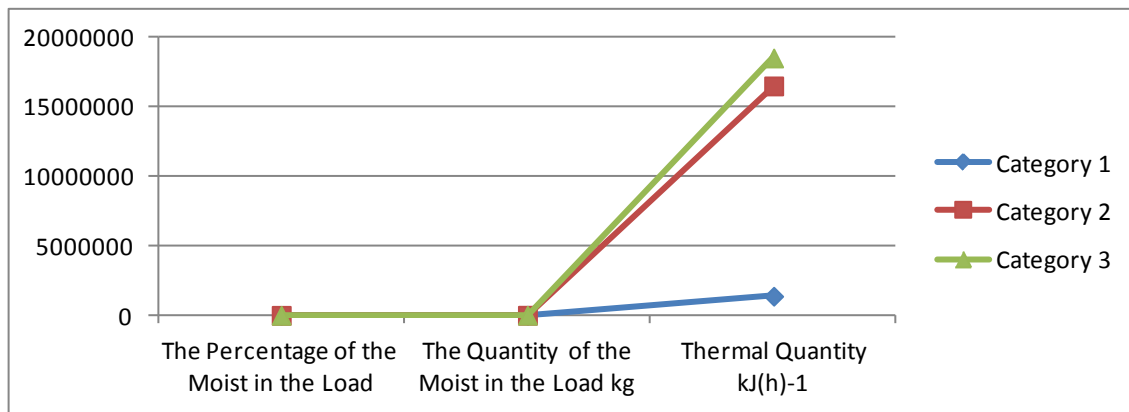


Fig. 2 The usage of the thermal quantity for vaporizing the moist from the load

2) The Loss of the Thermal Quantity with Dusts:

The thermal quantity lost with dusts from the furnace depends on the percentage of the particles of the dusts with gasses and the composition of the dust which is calculated with the expression:

$$Q_{\text{Dust}} = G_{\text{Dust}} \times C_{\text{Dust}} \times t_{\text{Dust}} \text{ k J (h)}^{-1} \quad (5)$$

The quantity of the dusts is calculated with the expression:

$$G_{\text{Dusts}} = G_{\text{load}} \times \% \text{ of dust in the load } \text{kg (h)}^{-1} \quad (6)$$

$$G_{\text{Dust}} = 56250 \times 1 \% = 562.5 \text{ kg(h)}^{-1}$$

t_{Dust} - the temperature of the dusts is 25 °C which are stored and measured in the plant.

C_{Dust} - the specific heat of the dusts is 0.128 kJ (kg °C)⁻¹

$$Q_{\text{Dust}} = 1800 \text{ k J(h)}^{-1}$$

3) The Loss of Thermal Quantity with Gasses:

The gasses of the melting process in the electrical furnace which are characterized with the composition of CO before they are used as a fuel for the rotational furnace are submitted to cooling and cleaning of the two degree venture system with the capacity of 3 000 m³ (h)⁻¹, as shown in Table III and Fig. 3.

TABLE III THE VALUE OF THE ENTHALPY OF THE GASSES DEPENDING ON THEIR TEMPERATURE

Temperature °C	Enthalpy kJ(m ³) ⁻¹
850	1156
900	1224
1000	1360

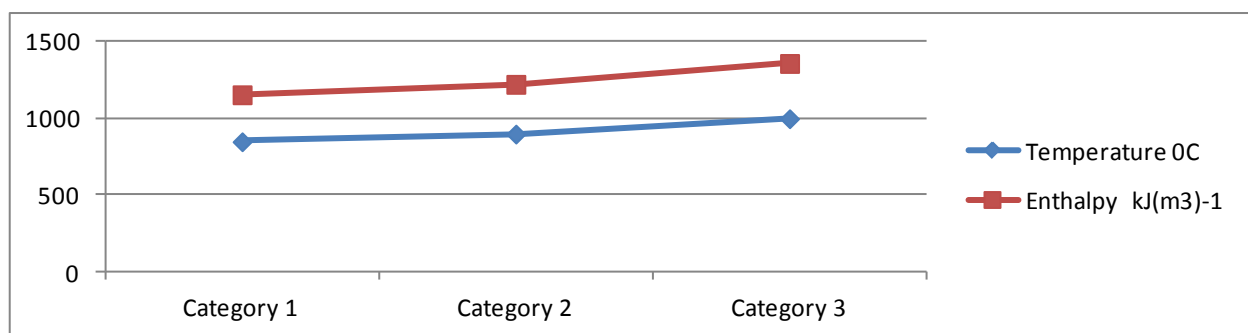


Fig. 3 The enthalpy of the gasses depending on the temperature

After the cooling and cleaning of the gasses in the 75°C and the composition of 30 mgr (m³)⁻¹ is used as a fuel for the rotational furnaces. The thermal quantity load with gasses that exit the furnace is calculated with the help of enthalpy and with the expression.

$$Q_{\text{gas}} = i_{\text{gas}} \times V_{\text{gas}} \text{ kJ(h)}^{-1} \quad (8)$$

i_{gas} - is the enthalpy of the gasses and is calculated with the expression:

$$i_{\text{gas}} = C_{\text{gas}} \times t_{\text{gas}} \text{ kJ(m}^3\text{)}^{-1} \quad (9)$$

C_{gas} - the specific heat of the gasses is 1.36 kJ(m³ °C)⁻¹

t_{gas} - the temperature of gasses on the exit of the furnace is 850°C and 1000°C measured in the plant.

$$i_{\text{gas}} = 1.36 \times 850 = 1156 \text{ kJ(m}^3\text{)}^{-1}$$

V_{gas} - the normal quantity of gasses is 7400 m³(h)⁻¹ measure in the plant.

$$Q_{\text{gas}} = i_{\text{gas}} \times V_{\text{gas}} \text{ kJ(h)}^{-1}$$

$$Q_{\text{gas}} = 1156 \times 7400 = 8554400 \text{ kJ(h)}^{-1}$$

Based on the expression (8) we calculate the thermal

quantity lost with gasses depending on their temperature and is presented in Table IV and Fig. 4.

TABLE IV THE THERMAL QUANTITY LOST WITH GASSES DEPENDING ON THEIR TEMPERATURE

Quantity of the Gasses $\text{m}^3(\text{h})^{-1}$	Enthalpy of Gasses $\text{kJ}(\text{m}^3)^{-1}$	Thermal Quantity $\text{kJ}(\text{m}^3)^{-1}$
7400	1156	8554400
7400	1224	9057600
7400	1360	10064000

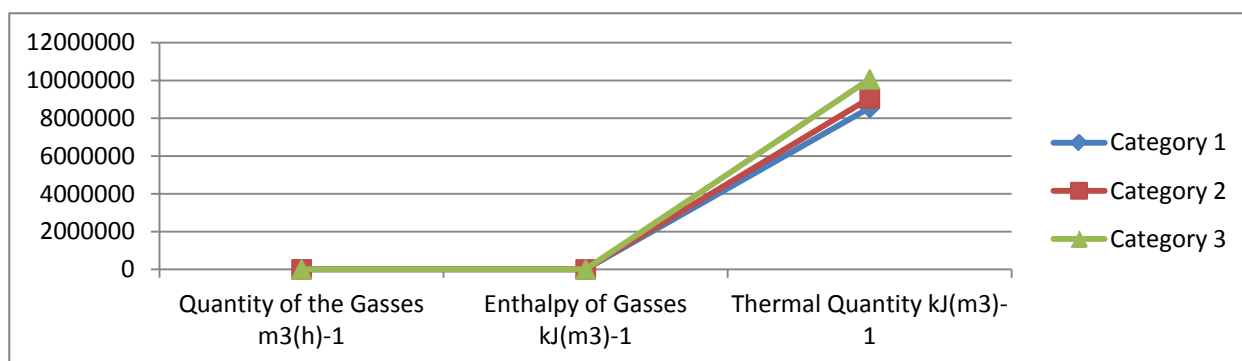


Fig. 4 The thermal quantity lost with gasses

TABLE V THERMAL QUANTITY THAT ENTERS THE FURNACE BASED ON THE EXPRESSION (9) AND IS DEPENDENT ON THE TEMPERATURE OF THE LOAD AND THE SILT

Temperature of the Load $^{\circ}\text{C}$	Temperature of the Silt $^{\circ}\text{C}$	The Thermal Quantity of the Load $\text{KJ}(\text{h})^{-1}$	The Thermal Quantity of the Silt $\text{kJ}(\text{h})^{-1}$	The Summation of the Thermal Quantity $\text{KJ}(\text{h})^{-1}$
700	25	19805625	19200	19821825
800	25	45000000	19200	45019200
900	25	50625000	19200	50644200

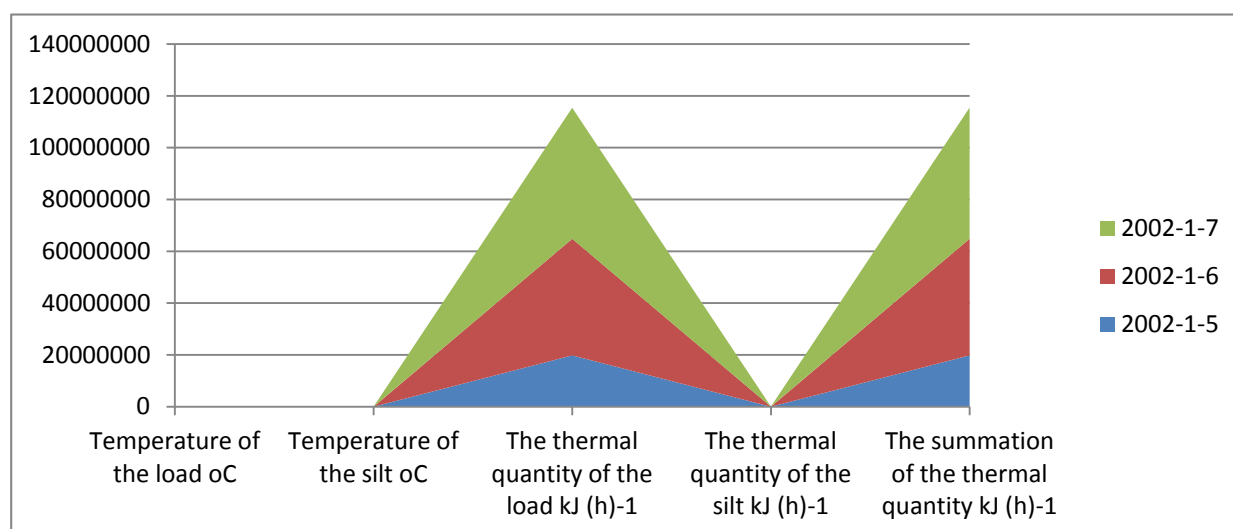


Fig. 5 The thermal quantity that enters the furnace

QUANTITY

V. RECAPITULATION OF THE BALANCE OF THE THERMAL

We have analyzed the thermal quantity in the high zone of the electrical furnace in the drying and roasting process of the

load for the oxidative-reductive zone. In an analytical, graphical and experimental manner we have calculated the

entry and exit thermal quantities and the thermal quantities used in this zone of the electrical furnace, as shown in Table V and Fig. 5.

In order to calculate the thermal quantity which enters the furnace we use the expression:

$$Q_{\text{hyn}} = Q_{\text{ferges}} + Q_{\text{lym}} \text{ kJ (h)}^{-1} \quad (9)$$

The thermal quantity which is used in this zone of the furnace, drying and roasting zone of the load is the thermal quantity which is used to vaporize the humidity from the load and is calculated with the expression (4) as shown in Table VI and Fig. 6

TABLE VI THE THERMAL QUANTITY THAT EXISTS IN THE FURNACE WHICH IS DEPENDENT ON THE TEMPERATURE OF THE GASSES AND DUSTS CALCULATED WITH THE EXPRESSION (10)

Temperature of the Gasses °C	Temperature of the Dusts °C	The Thermal Quantity of Gasses (h) ⁻¹	The Thermal Quantity of the Dusts kJ (h) ⁻¹	The Summation of the Thermal Quantity kJ (h) ⁻¹
850	25	8554400	1800	8556200
900	25	9057600	1800	9053400
1000	25	10064000	1800	10065800

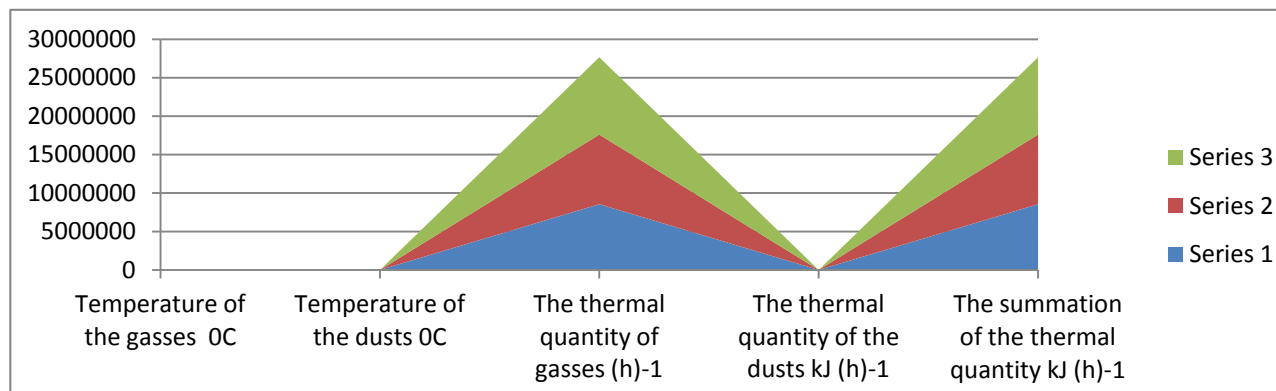


Fig. 6 The thermal quantity that exists the furnace

TABLE VII THE DIFFERENCE OF THE THERMAL QUANTITY WHICH DEPENDS ON THE TEMPERATURE OF THE LOAD AND ITS HUMIDITY AS WELL AS THE TEMPERATURE OF THE GASSES CALCULATED WITH THE EXPRESSION

Temperature °C	Thermal Quantity that Enters the Furnace k J (h) ⁻¹	Thermal Quantity that Exist in the Furnace k J (h) ⁻¹	Thermal Quantity which is Used for vap. of Moist k J (h) ⁻¹	Difference of the Thermal Quantity k J (h) ⁻¹
800	45019200	8556200	16529400	19933600
900	50644200	9053400	18543538	23047262

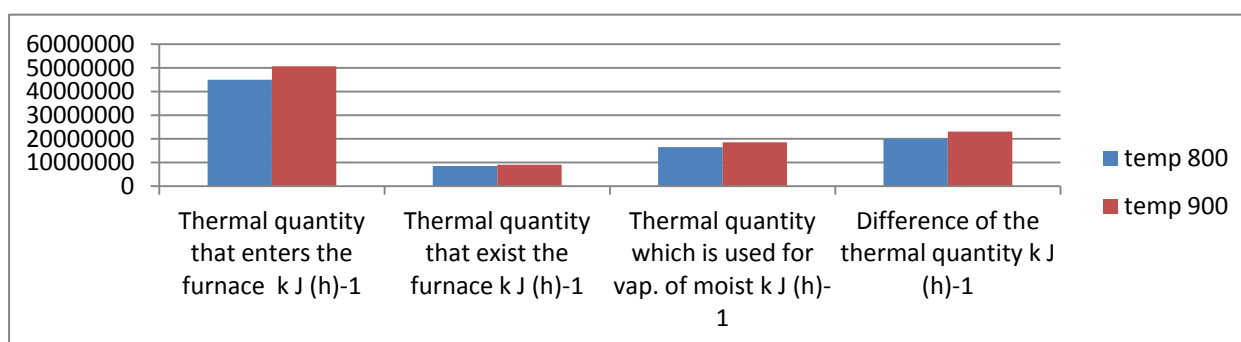


Fig. 7 The difference of thermal quantity which depends on temperature and humidity of the furnace

The thermal quantity which exits the furnace is calculated with the expression:

$$Q_{\text{dej}} = Q_{\text{gass}} + Q_{\text{dusts}} \text{ kJ (h)}^{-1} \quad (10)$$

The difference of thermal quantity in this zone of the furnace is calculated with the expression, and is shown in

Table VII and Fig. 7.

$$Q = Q_{\text{entry}} - Q_{\text{vap.humd}} - Q_{\text{exit}} \text{ kJ (h)}^{-1} \quad (11)$$

V. CONCLUSION

According to the calculations we can conclude on all points of views of thermal balance that thermal quantities acquired with the load and silt and thermal quantity for vaporizing humidity from the load and as well as thermal quantity lost with gasses and dusts in this zone do have positive values that are acceptable for the melting process in the electrical furnaces. Based on the analytical, graphical, and experimental calculations of the thermal quantities which enter the furnace are dependent on the quantity and temperature of the load and the quantity of silt. The quantity of humidity in the load and the quantity of gasses in this zone of the furnace should be kept in control on these values as below:

The humidity of the load should keep the limits (10-13) %. The quantity of gasses should be $\leq 7400 \text{ m}^3 (\text{h})^{-1}$ and with minimal composition of oxygen. Based on the values of the thermal quantity which enters the furnace, thermal quantity used and thermal quantity lost in this zone we can conclude.

As for the load with a temperature of 800oC we have 36.71% of the entry thermal quantity in the furnace which is used for vaporizing the humidity from the load. Thus, 19.005% of the entry thermal quantity in the furnace is lost with gasses and dusts. Yet, 44.279% of the entry thermal quantity in the furnace is left on the process and is used for the melting of the load in the furnace.

As for the load with the temperature 900oC we have an increase of 1.279 % of the thermal quantity which is left on the

process and a 1.238% decrease of the thermal quantity which is lost with gasses and dusts with what we have an increase in the economic and environmental sustainability in the melting process of the electrical furnaces.

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